THE ENERGY OBSERVER

Energy Efficiency Information for the Facility Manager

Quarterly Issue – June 2007

Variable Frequency Drives

The Energy Observer summarizes published material on proven energy technologies and practices, and encourages users to share experiences with generic energy products and services. This quarterly bulletin also identifies informational sources and energy training for facility managers and staff. ***The Energy Observer*** is a service of the **Energy Office, Michigan Department of Labor & Economic Growth.**

This issue focuses on variable frequency drives, or VFDs, and how they can help reduce energy costs. A VFD is a system for controlling the rotational speed of an AC electric motor by controlling the frequency of the electrical power supplied to the motor. VFDs can be installed in existing motor systems and can operate both standard and high-efficiency motors in a wide range of sizes, from less than one horsepower to several thousand hp. Installation is easy because they can be located remotely and do not require mechanical coupling between the motor and the load.

How VFDs Work

Variable frequency drives operate under the principle that the synchronous speed of an AC motor is determined by the frequency of the AC supply and the number of magnetic poles in the motor, according to the equation:

$$RPM = \frac{120 \times f}{p}$$

where:

RPM = Motor speed, in revolutions per minute, f = AC power frequency (hertz), and p = the number of poles (an even number)

Therefore as the frequency supplied to the motor is decreased, the speed also decreases.

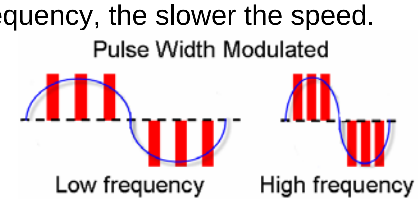
System Components

- **Operator Interface**

The operator interface provides the means for the operator to start and stop the motor. In addition, the operator interface allows the user to switch between manual speed control and automatic control. Automatic control usually means the frequency output from the VFD is controlled by an external sensor via a feedback control circuit.

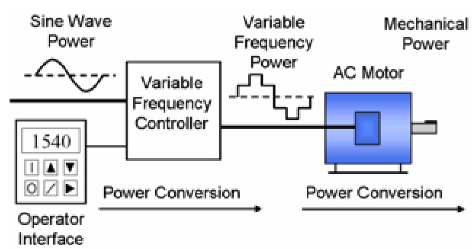
- **Controller**

The controller is an electronic device which converts the incoming three-phase power to an electronic signal. This signal's frequency can be changed by the operator interface, or can be regulated by an external sensor. Most often, especially with new VFDs, this output signal is Pulse-Width Modulated (PWM), whose frequency controls motor speed. In other words, the higher the frequency, the faster the speed, the lower the frequency, the slower the speed.



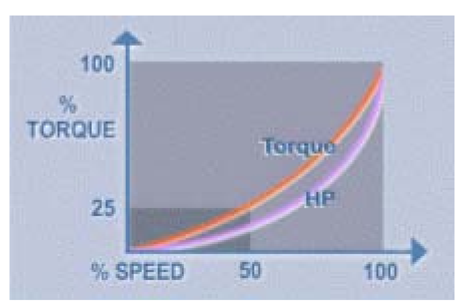
- **Motor**

Many times, the motor being controlled is a three-phase induction motor, which is most often designed for fixed-speed mains voltage.



How VFD's Conserve Energy

Energy savings are possible with VFDs, because often machines such as fans are run at a fixed speed based on the supply power with complete disregard for actual load requirements. Controlling a variable-torque load such as a fan or pump with a VFD results in considerable savings because torque varies as the square of speed and horsepower varies as the cube of speed. For example, if fan speed is reduced by 20%, motor horsepower (energy consumption) is reduced by 50%. See graph below.



Applications

- **VAV HVAC fans**

Airflow in older variable-air-volume systems is usually controlled by opening and closing dampers or inlet vanes. These systems often operate at low airflow, and switching to VFDs offers a tremendous opportunity for energy savings. The VFDs can vary motor speed in order to match fan output to varying HVAC loads, negating the need for dampers or inlet vanes.

- **Cooling tower fans**

Cooling towers contain large motors with fans operating continuously for long periods of time, under seasonally and daily-varying loads. A VFD can change motor speed to achieve the maximum efficiency for a given load.

- **Water pumps**

Pumping systems can be made variable by sequencing fixed-speed pumps and a single variable-speed pump. This cuts installation costs.

- **Industrial applications**

VFDs can be especially practical in applications such as grinding and materials handling, where precise speed control is required.

- **Geothermal systems**

The long hours of annual operation, particularly at low heating and cooling loads, provide lots of savings potential.

Cost

Costs for basic variable frequency drives start at around $520/hp for a one hp drive and then drop sharply to around $160/hp for a 10 hp drive. 40 hp drives typically cost around $100/hp, and 500 hp drives are around $70/hp. However, costs can be doubled by installation costs, electrical filters, and special features for constant torque, controls, or diagnostics.

Case Study

A rubber manufacturer recently installed a VFD on a 1,500 hp motor used to power an extruder, which is used to blend various solids, oils, carbon and other chemicals. Prior to installing the VFD, the plant used an electromagnetic, eddy-curent clutch to control motor output. The clutch was replaced by the VFD, which allowed the plant engineer to alter the voltage frequency to the motor allowing for precise speed control and maximum energy savings. Installation was completed during a maintenance shutdown period, and preparation of a clean room and initial installation of the drive took several months.

The rubber manufacturer now saves 1.3 million kWh per year with the VFD producing an annual electricity bill savings of over $40,000. Analysis of extruder operation with the VFD shows that more than 40% of the extruder's energy consumption was wasted through the clutch controller. Electricity savings alone provided the plant with a payback of just under six years.

The drive also improved extruder operation. With the VFD, the unit can be brought online at very low RPM and ramped up, eliminating the need to shut down and clean out the unit after long periods of idle. This saved the plant more than 240 man-hours per year in labor costs. The VFD improves product consistency because it can adjust batch speed to continuously maintain desired temperatures. The VFD also provides a soft-start capability that will prolong the life of the motor and lower mechanical stress on the extruder.

More information about variable frequency drives can be found on these websites:

http://www.oee.nrcan.gc.ca/industrial/equipment/vfd/index.cfm?attr=24

http://www.drivesmag.com/

http://www.motorcontrol.com/2007HomePageLinks/acdrives.htm

http://www.nema.org/

http://www1.eere.energy.gov/industry/bestpractices/pdfs/38947.pdf

http://www1.eere.energy.gov/femp/pdfs/29267.pdf

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